Hauling Down More Water From the Sky

Chas. Gardner, Jr.

There is a river in the sky—a complex, swirling, tumultuous river of air and water.

Sometimes we cannot see the water, when it is in the form of vapor. At other times, airborne droplets of water gather in clouds, which, of course, can be seen. We should not assume that clouds contain water and the surrounding air does not, because the surrounding air carries vapor, which often flows into the cloud. And, also, clouds dissolve into vapor and fade away. But the clouds we see with our eyes contain water brought along a step in the process of becoming rain.

With clouds we can have rain. Without clouds we cannot.

But with clouds we do not necessarily have rain. The droplets of water often fail to take the further step of becoming raindrops, accretions of water heavy enough to fall to the ground.

This exasperates the farmer—when lush clouds, apparently containing a great deal of moisture, float over his dry fields and fail to precipitate out even one small part of the moisture carried by and flowing into these clouds. Cloud census studies have shown that seasons with considerable cloud cover can also be dry seasons.

Why? Can we coerce the droplets into becoming drops heavy enough to fall onto the ground? Can we haul down needed moisture from the sky?

A FEW YEARS AGO many of us thought we had the answer. For some time it had been theorized that minute particles of dust, present throughout the atmosphere, were a necessary ingredient of rain, something for the droplets to cluster on and grow. In 1946 Dr. Vincent J. Schaefer, of the General Electric Co., sprinkled particles of dry ice from an airplane and produced precipitation. A little later Dr. Bernard Vonnegut of General Electric ran onto silver iodide as the ideal particle or crystal. A few experiments produced seemingly awe-inspiring results.

And so, "scientific rainmaking" came into being. The scientific basis of it was "artificial nucleation"—that is, the supplying of artificial nuclei or particles to clouds thought to lack sufficient natural nuclei.

A comment on terminology should be inserted at this point. The word "rainmaking" seems to imply the creation of water, whereas so-called rainmakers cannot produce water that does not already exist in the air. Perhaps "rain increasing" should be used. Further, the phrase "weather control" implies a management of the elements beyond present conception. Perhaps "weather modification" states more accurately what we can now visualize. The terms "rainmaking" and "weather control," however, have become common and are more easily recognized.

Artificial nucleation is tied in with the ice crystal theory. According to the theory, natural ice crystal formation occurs at quite low temperatures ($-40°$ F.). Presumably the crystals grow by attracting other moisture particles until they become heavy enough to fall out of the clouds as snow, which melts on the way down and becomes rain.

Dropping dry ice (carbon dioxide) on clouds cools areas of those clouds and starts the process of crystal formation. The effect can be substantial if the clouds are near the temperature at which ice crystals form naturally.

Supplying nuclei to clouds does not cool them, but with nuclei the ice crystal formation occurs at higher temperatures—that is, below freezing but closer to the freezing level. Some natural nuclei or dust particles start the process at temperatures between $-40°$ and $5°$. But crystals of silver iodide (artificial nuclei) start it between $5°$ and $25°$.

Therefore, silver iodide not only can

start rainfall in clouds too warm for natural rainfall production but can increase rainfall in clouds already producing small amounts by nucleating the warmer lower sections.

Another method of producing rainfall is of interest, although not of commercial importance. In warm regions, nonfreezing clouds release rain, obviously by some other process than the formation of ice crystals.

It is commonly believed that precipitation results when larger than normal water droplets fall relative to other droplets, collecting enough smaller ones to grow to raindrop size large enough to fall out of the cloud. The answer lies in providing the larger droplets.

Such clouds, found in the Southern States and farther north in the summer, have been successfully seeded by water sprayed from airplanes.

But airplanes cost money to operate and flying them into storm clouds can be dangerous. The large commercial "cloud-seeders" therefore do not use dry ice or water but rely on silver iodide, which can be released from ground generators. The minute crystals drift away from the generators and presumably get sucked into the updrafts of storm clouds.

ARTIFICIAL NUCLEATION has had a big impact on the Nation, particularly, but not exclusively, in the West, where more water is almost always desirable. To those who have studied the economic aspects, it seems elementary that the Eastern and Southern States can reap more benefits dollarwise from rainmaking—if it works as some experiments suggest it may—than the dry areas of the Southwest.

During a recent year the "target areas" of scientific rainmakers in this country comprised 13 times as many acres as those under irrigation. One study showed that 20 percent of the Nation's area was covered with rainmaking efforts.

The estimates are rather haphazard and perhaps misleading, but they do suggest that rainmaking is a pretty big business, even with its uncertainties.

A recent survey of the Advisory Committee on Weather Control, a temporary Federal agency set up to "find out who is doing what, and with what results," revealed that 13 States had already passed legislation having to do with rainmaking. Eight States had legislation pending.

Most of this legislation has assumed that the rainmakers really have modified the weather significantly—an assumption that a majority of scientists familiar with the subject do not go along with wholeheartedly. Most of them seem to agree that nucleating agents can modify weather in certain circumstances. Some think these circumstances occur frequently enough so that man can change the whole pattern of water distribution in the United States, with a tremendous impact on the economy. Others are skeptical of large-scale effects. Most of them say: "A lot more has to be learned about the rainmaking process before we can tell."

Anyway, it is of interest that five legislatures, composed mostly of practical laymen, have proclaimed their States' sovereignty over the atmospheric moisture floating above their States. Those legislative bodies have shown concern over the possibility that the other States might somehow steal moisture that rightfully was theirs.

THIS IS THE ROBBING-Peter-to-pay-Paul argument that has loomed large in the minds of many people in the West. They believe that rain increasing in upwind areas must necessarily mean rain lessening in the downwind areas. People in the Southwest who have suffered from droughts these past years have taken this argument to heart.

The rainmakers answer the argument by saying that Nature is an inefficient rainmaker, with only about 1 percent of a cloud's moisture falling to the ground in an ordinary storm. By supplying more nuclei they may increase this efficiency up to 2 percent.

Such amounts are insignificant, they say, and the vast streams of moisture floating in the sky will replenish the clouds almost immediately.

Whatever the merits of this, rainmaking, viewed on a grander scale, may indeed increase substantially the amount of mineral-free water available for man's use.

FOR ONE THING, it seems perfectly obvious that many airborne streams of moisture escape the land and give much of their water back to the seas. Rainmaking might make it possible for us to take better advantage of the rain potential of these airborne streams before they get away. For another thing, it has been suggested that precipitating moisture out of clouds at earlier stages of storm development might speed up the hydrologic cycle and establish a new rainfall regime. This would mean more use and reuse of airborne moisture.

But even if rainmaking could not increase the net amount of moisture on the ground, it might yet affect the distribution of this moisture in such a way as to produce tremendous economic benefits.

DOES IT REALLY WORK? That is the question farmers ask. Scientists reply that it does in certain circumstances.

Seeding with dry ice and water admittedly has modified clouds and has produced precipitation. Silver iodide can do the same.

But scientists disagree as to whether the more economic method of seeding clouds by means of ground generators has produced, or can produce, the substantial increases in rain and snowfall claimed by the private "cloud-seeders."

The problem of evaluation is inherent in the ground-generator method. Seeding with dry ice or water, the operator can usually turn around and see the results. The seeded clouds often change form and precipitation falls before his eyes. But when he releases silver iodide from a generator he cannot see the material. Does the generator produce the right-sized crystals? Do they get into the storm clouds in the right quantities at the right altitude? Does the silver iodide retain its effectiveness or does it decay because of temperature, pressure, or exposure to ultraviolet rays. There can be many a slip twixt the cup and the lip.

The fact that he seeds during storm situations, usually when at least some rain falls naturally, makes visual observation impossible in most cases and makes measurement of any manmade increase extremely complicated.

And so, instead of seeing the cause and effect, he has to guess. And he has to attempt a measurement of the manmade increase by means of statistical evaluation. He has to compare the "target area" rainfall with rainfall of past years or, more commonly, with rainfall received in adjacent areas.

Statistical analyses—usually provided by the cloud-seeder himself and imperfectly understood by the layman—can often show spectacular and convincing results. But sometimes other persons can work over the same figures and get different results. And sometimes the statistical people can bury good results in a pile of figures. Thus the controversy.

The analyses themselves get complicated, but the problem of analysis can be stated quite simply.

When the target area gets more rain than outside areas, say three control areas labeled "A," "B," and "C," the cloud-seeder usually satisfies his clients. Yet the center of a storm may have passed over the target area to produce the result naturally and the cloud-seeder may have done nothing.

When the target area gets more rain than A and B, but less than C, the clients may nurse a small doubt or two. And when the target area gets less than A, B, and C—then they become skeptics. Yet in both cases the cloud-seeder may have increased rainfall on the target area over the amount which would have fallen naturally.

Rainfall results in the target areas

usually fall within the realm of historical variation. We can always suspect, therefore, that increases are only accidental. If we only knew how much rain would have fallen naturally, we could evaluate perfectly. This we can never know and we have to satisfy ourselves with a statistical substitute.

Failure to understand this problem leads to confusion. Many farmers become enthusiastic believers; others, confirmed skeptics. The experimental work financed by farmers and ranchers proceeds, therefore, on an uneven and haphazard basis and does not provide a great deal of data of value in determining the actual, overall results. To avoid dealing with large groups with some conflicting interests and opinions, some cloud-seeders perform work only for corporations, particularly public utilities that produce hydroelectric power. But farmers continue to support projects, principally because cloud seeding costs only pennies (5 to 10 cents an acre usually)—while added rainfall means dollars.

A STUDY of an entire river basin in the United States, based on physical assumptions considerably more modest than some cloud-seeders have asserted, showed a benefit-cost ratio of 20 to 1. Obviously experiments in certain areas—possibly mountain areas where air movements should naturally lift the silver iodide smoke into the clouds and where temperatures should be more favorable—these should show a higher benefit-cost ratio. Experiments in some areas should prove to be more nearly marginal.

Experiments in the United States have attracted a great deal of interest in foreign countries. At least 26 countries, on every continent except Antarctica, have carried out experiments in recent years.

Farmers in South Africa have used rockets to disperse silver iodide at high altitudes, the purpose being to reduce hail damage. Farmers in the Bayonne region of France have used ground generators for the same purpose. The theory of hail prevention is that, by precipitating out moisture at earlier stages, cloud seeding can prevent large hail-producing storms from developing. The same theory applies to lightning prevention and thus has interest for those who have responsibility for fighting forest fires. Some cloud-seeders in the United States like hail-prevention projects because while farmers do not always want more rain they almost always want to prevent hail if they can. Thus such projects sometimes get a steadier financial support.

Formosa and Sweden have undertaken projects to increase hydroelectric power. Owners of sugar plantations in Cuba have financed rain-increasing projects despite an average of more than 60 inches of rainfall a year. Additional rainfall means additional sugarcane for them.

Much of the work in foreign countries has been of high caliber. But it still has not supplied the answers.

RECOGNIZING THE PROBLEM of evaluation, the Congress created an Advisory Committee on Weather Control, which began work on July 1, 1954. Senator Francis Case of South Dakota and Senator Clinton P. Anderson of New Mexico, a former Secretary of Agriculture, the principal authors of the bill, started pushing for legislation in 1950.

The Advisory Committee, a temporary Federal agency, was directed to "study and evaluate public and private experiments in weather control" and to recommend the extent to which the United States should "engage in, experiment with or regulate" weather control activities. The Congress set June 30, 1956, as the date for submission of a final report.

Why a Federal committee? For one thing, the Congress felt it could make an independent and impartial evaluation, free from any bias which could be alleged, rightly or wrongly, against the evaluation of the cloud seeders. For another, it could survey the whole field of experiments, not just one or a few. The law provided authority to demand reports from the seeders.

Analysis of experiments will produce some answers helpful to farmers and other water users in deciding whether weather control activities are a good bet or not. But the real and positive answers will come from further research into rainfall processes. The sky is a wild, unpredictable laboratory; research in weather is difficult and often frustrating. All the same, science moves inexorably onward, learning more and more about the possibilities for modifying or controlling weather.

Perhaps these possibilities will narrow down to certain limited applications. It is conceivable, though, that weather control can become a regular feature of crop production.

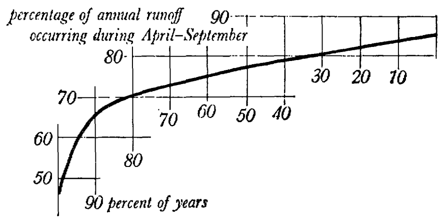
CHAS. GARDNER, JR., *became executive secretary of the Advisory Committee on Weather Control in 1954. He previously served as executive secretary to the South Dakota Natural Resources Commission. He is a graduate of Yankton College, the University of Missouri, and McGill University, and has studied at the University of London.*

Measuring Snow To Forecast Water Supplies

R. A. Work

A large part of the annual flow of the rivers in our Western States is delivered in spring and summer. That is because precipitation on the high, mountainous watersheds falls mainly as snow, and as snow it is held through the winter until springtime warmth melts it and releases it to the valleys below.

Elsewhere in the West the ratio of seasonal flow to total annual flow is always high, but it varies from stream to stream or from year to year on the same stream. That makes essential the forecasting of the seasonal flow, which usually occurs in April–September, the period of least—or no—rainfall and the season of greatest need for water for crops. It also is the time when snowmelt may cause widespread destructive floods.



This graph shows the relationship of the seasonal flow (April-September) to the total annual flow (stream year of October-September) for a typical western snowfed stream—the South Fork of Ogden River, measured near Huntsville, Utah. The stream is used extensively for the irrigation of small farm units. In 50 percent of the years, more than 75 percent of the total runoff occurs during the irrigation season—April-September. The recorded seasonal delivery historically ranges from 45 to 88 percent of the total annual runoff.

TO MEASURE THE AMOUNT of snow on the watersheds and thereby foretell the flow of rivers months later, snow surveys are undertaken in the western mountains. The surveys were developed originally to forecast the seasonal supply of water for irrigation. They have become tools for better water management by industry, power companies, municipalities, flood control agencies, conservation agencies, fisheries, wildlife organizations, and others.

Records, history, and the growth of the West give other reasons for this important work.

Our records show that precipitation (and runoff) may depart markedly from the mean in any year or by smaller amounts for a connected series of years. For periods of 20 to 30 years or more, the general pattern of precipitation for a locality or a basin might remain nearly continuously above or below the recorded mean.

The accompanying graphs of annual precipitation for the stream year (October-September) and of the an-